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Quality analysis of plastic sachet and bottled water brands produced or sold in Kumasi, Ghana

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Abstract

In this study, physical, chemical and bacteriological qualities of bottled and plastic-bagged drinking water sold and/or produced in Kumasi, Ghana, were examined to compare their compliance with World Health Organisation (WHO) and Ghana Standard Authority (GSA) standards. One hundred and ninety-eight (198) samples representing 22 brands from 5 bottled water and 17 plastic-bagged water were collected randomly from street vendors, local markets and shops and analysed for physical, chemical and bacteriological water quality parameters using WHO analytical methods. Temperatures of all the samples analysed were higher than the WHO/GSA standard. Forty percent (40%) of the bottled water and 5.88% of plastic-bagged water had pH values lower than WHO/GSA standard. All other physical and chemical parameters analysed were within the WHO/GSA acceptable standards. Total coliforms, faecal coliforms and enterococci bacteria were not present in any of the water brands. The results of this study indicate that bottled and sachet drinking water produced and/or sold in Kumasi, Ghana, are of good quality for consumption.

Keywords: Bottled water; Drinking water quality; Kumasi metropolis; Sachet water

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1. Introduction

Water borne diseases are one of the major health problems especially in developing nations. The high prevalence of disease such as diarrhoea, typhoid fever, cholera and bacillary dysentery has been linked to the consumption of unsafe water produced under unhygienic production practices. Water quality is generally defined as the physical, chemical and bacteriological characteristics of water in relation to the requirements to human need (Johnson et al., 1997; Diersing, 2009). In Ghana, the required physical, chemical, microbial and radiological properties of drinking water is regulated by the Ghana Standard Authority (GSA) standards for drinking water (GS, 1998), which is adopted from the World Health Organizations (WHO) Guidelines for Drinking Water Quality (WHO, 1993, 1996, 2001, 2002).

The sale and intake of "iced water", which was being sold from a bucket with a single cup or sometimes few cups shared for all consumers was a common practice in Ghana in the 1980s and 90s. However, alarming concerns of infectious and easily transmitted diseases such as tuberculosis (T.B), typhoid and cholera gave rise to the emergence of hand-filled and hand-tied polythene bagged water in the mid 1990's as improvement on the shared cup-served "iced water". Yet, this was noticed to be prone to risk of contamination during production since bare hands were used in each stage of the production (Obiri-Danso et al., 2003). For instance, filtration was being carried out by the use of foam fixed unto the end of a water hose or funnel. Also, the polythene bags were opened by mouth-blowing of air, which was potential source of introducing bacteria and sealed by tying a knot at one end; again by hand without any form of sterilization.

The production of factory based bottled water and plastic-bagged water (or "sachet water") popularly called "pure water" was introduced in Ghana as an improvement on the hand-filled and hand-tied plastic water. The consumption of these factory based packaged water products in Ghana continue to increase since its introduction in the past decade. According to Green and Green (1994), and Hunter (1994), this increase in consumption of packaged water is mainly due to factors such as (i) the lack of reliable, safe and quality drinking water in the urban areas, (ii) changes in life style towards the consumption of branded water and, (iii) mad rush of people into bigger shops to request for good drinking water. This high demand for packaged water led to the emergence of small-scale entrepreneurs in the production of packaged water without due cognizance of standard hygienic production practices.

The hygienic standard in the various stages of production of sachet water is similar to that of bottled water. For instance, carbon filter bed used in bottled water production, is also used in sachet water production to remove some contaminants. Sealing of the filled sachet bags is also done using heating sealing machines (Hunter and Burge, 1987). Interestingly, although the public have strong doubt of the quality of treated tap water enjoyed in their homes, the common source of water for both sachet and bottled water in Ghana is either treated piped water or well water, which may not be entirely free from bacteria and other contamination. A study of the quality of tap drinking water in the Kalama region of Egypt showed that 30% of water samples were contaminated with at least one coliform or pathogenic bacterium (Ennayat et al., 1988), and 36% reported for a similar study in Quebec City of Canada (Levesque et al., 1994). Bacteria and virus contaminants reportedly found in bottled and sachet water are pathogens such as coliform bacteria or Escherichia Coli, Pseudomonas, vibrio cholera, which enter packaged water through seepage of sewage into well water or as contaminants during bottling or bagging (Defives et al., 1999). GSA standards and WHO guidelines for drinking water quality (GS, 1998; WHO, 2001, 2002) stipulate that drinking water should be free of human enteroviruses.

Recent reports indicated that most of the factory made sachet water products in Ghana are unwholesome for human consumption, as a result, twenty-five (25) "pure water" firms in the Accra Metropolis alone were closed down by the Food and Drugs Authority (FDA) when it was realized that some of the companies are either operating in unhygienic conditions or filthy environments or not registered with the FDA (Ofori, 2011; Mensah, 2011). Surprisingly, some vendors are reported to be capitalising on the perceptible public loss of trust in the purity of sachet water, and thus, are refilling empty bottles of reliable bottled water brands with sachet water on sale (Ghanaian Times, 2011).

Although the proliferation of these factory based packaged water products in Ghana has created numerous employments especially in the urban areas, and thus providing economic benefits to the country, the consumption of these so called "pure water" has generated several alarming health related criticisms that need to be investigated. This among other concerns necessitates the need for a scientific investigation into the quality of packaged water produced and/or sold in the Kumasi Metropolis.This study therefore analyses the physical, chemical and bacteriological quality parameters of randomly selected sachet and bottled drinking water products sold and/or produced in the Kumasi Metropolis in Ghana to determine whether they meet the quality standards of WHO and GSA.

2. Materials and methods

Kumasi was chosen as the study area because the city is the second largest, and also the second most populated urban city in Ghana. There are numerous sachets and quite a number of bottled drinking water sold and/or produced in Kumasi, with consumption of sachet water higher than bottled drinking water owing to cost difference.

2.1. Sampling of bottled and sachet water

Seventeen (17) sachet and 5 bottled drinking water brands; given a total of 22 brands from different manufacturers were used for the study. These are the most popular and consumed brands in Kumasi. Triplicate batches of each brand were purchased randomly from local markets, shops and street vendors within the Kumasi Metropolis. The samples were clearly marked for easy identification, and transported to the Quality Assurance Laboratory of Ghana Water Company Limited in Kumasi for immediate analysis. Each product was carefully opened to avoid contaminating the water. For bottled water, the cap of each bottle was carefully removed to avoid touching the opening. In the case of sachet water, an edge of the package was cut with a sterilized scissors and carefully placed in a sterilized beaker. The physical, chemical and bacteriological parameters were determined by taking water directly from the original package (sachet or bottle) and tested. Forty-five (45) bottled samples and 153 sachet water samples were analysed, with 9 samples from each brand for a total 198 samples.

2.2. Physical analyses

Temperature was measured using Standard Method 2550 B: Laboratory and Field Methods, using a multipurpose pH meter (HANNA pH 209, U.S.A) adjusted for temperature in Degrees Celsius (^oC), as detailed in Standard Methods for the Examination of Water and Wastewater (APHA, 2005). Colour was determined using Standard Method 2120 C: Spectrophotometric Method, with an ultra violet (U.V.) spectrophotometer (HACH LANGE DR 5000, U.S.A.) expressed in hazen units (HU), according to Standard Methods for the Examination of Water and Wastewater (APHA, 2005). The turbidity was measured using Standard Method 2130 B: Nephelometric Method, by turbidimeter (HACH 2100P, U.S.A) in Nephelometric Turbidity Units (NTU), as explained in Standard Methods for the Examination of Water and Wastewater (APHA, 2005). Conductivity was determined using Standard Method 2510 B: Laboratory Method, via a conductivity meter (JENWAY 4510, U.K) in micro-Siemens per centimeter ($\mu s/cm$), as detailed in Standard Methods for the Examination of Water and Wastewater (APHA, 2005). Total dissolved solids (TDS) and total suspended solids (TSS) were determined using Standard Methods 2540 B: Total Dissolved Solids Dried at 103-105°C and 2540 D: Total Suspended Solids Dried at 103–105°C, respectively. The units were expressed in mg/L according to Standard Methods for the Examination of Water and Wastewater (APHA, 2005).

2.3. Chemical analyses

Alkalinity was determined using Standard Method 2320 B: Titration Method in mg/L, as explained in Standard Methods for the Examination of Water and Wastewater (APHA, 2005). Total hardness and calcium hardness were determined using Standard Method 2340 C: EDTA Titrimetric Method and Standard Method 3500-Ca-B: EDTA Titrimetric Method, respectively, as detailed in Standard Methods for the Examination of Water and Wastewater (APHA, 2005); expressed in mg/L. Chloride was analysed using Standard Method 4500-Cl^- B: Argentometric Method in mg/L, and pH measured using Standard Method 4500-H^+ B: Electrometric Method, by a multipurpose pH meter (HANNA pH 209, U.S.A), according to Standard Methods for the Examination of Water and Wastewater (APHA, 2005).

2.4. Bacteriological analyses

Total coliform and faecal coliform organism numbers were determined using Standard Method 9221 B: Standard Total Coliform Fermentation Technique. Heterotrophic bacteria were enumerated using Standard Method 9215 C: Spread Plate Method, according to Standard Methods for the Examination of Water and Wastewater (APHA, 2005). Gallenkamp, Economic Incubator Size 2, England was used. The number of colony forming organisms was counted manually, and again, bottles inspected for the formation of acids and gases in vial.

3. Results and discussion

Results of physical, chemical and bacteriological quality characteristics of bottled and plastic-bagged (sachet) drinking water analysed were compared with the recommended WHO guidelines (WHO, 1993, 1996, 2001) and GSA standards (GS, 1998) for quality water. The results obtained were statistically analyzed in Excel and GraphPad to test whether they differ significantly at 95% (0.05) confidence level from the standards.

3.1. Physical quality parameters

Table 1 shows the physical parameters namely temperature, colour, conductivity, total suspended solids, turbidity and total dissolved solids for the bottled and sachet water brands investigated. Temperature values of bottled water samples ranged from 28.70 to 29.30 ^{o}C (averaging 28.94 ^{o}C) whereas that of sachet (plastic-bagged) drinking water samples ranged from 28.40 to 29.00 ^{o}C (averaging 28.81 ^{o}C) as shown in Table 1. This means that the average temperature for the bottled water samples were higher than that of the sachet water. Temperature values obtained for all the bottled and sachet water samples were higher than the WHO/GSA standard of 25 ^{o}C; and their mean values statistically differ significantly at 95% (0.05) confidence level from the WHO/GSA standard values for quality water. This could be due to the average room temperature (28 to 33^{o}C) in Kumasi during the experiment. These temperatures obtained for sachet and bottled drinking water fell within the optimal growth temperature (20–45^{o}C) for mesophilic bacteria including human pathogens (Prescott et al., 1999). The microbiological characteristics of drinking water are related to temperature through its effects on water-treatment processes and its effects on both growth and survival of microorganisms (WHO, 1996).

Consequently, growth of nuisance microorganism is enhanced by warm water conditions and could lead to the development of unpleasant tastes and odours (Pangborn and Bertolero, 1972). However, a report by State Water Quality Control Board in Canada indicated that the survival time in water of the cysts and ova of parasitic worms such as *Schistosoma* ova is shortened by higher temperatures between 29 to 32^{o}C (McKee and Wolf, 1963).

From the results obtained shown in Table 1, conductivity values for bottled drinking water ranged from 5.93 to 93.20 µs/cm (averaging 37.92 µs/cm). Values obtained for sachet water brands were between 22.80 and 146.60 µs/cm (averaging 73.45 µs/cm), in which 5.88% had 22.80, 75.50, and 85.00 µs/cm each. Also, 11.77% of the sachet water had conductivity values between 94.10 and 94.3 µs/cm; 17.65% from 136.90 to 146.60 µs/cm; 23.53% between 51.50 and 57.00; and 29.41% had values in the range of 47.60 to 48.7 µs/cm. Importantly, although the average conductivity values for the sachet water brands were higher than that of bottled waters, all the values obtained for each type were far below the maximum WHO/GSA standard value (1000 µs/cm). This clearly showed that the bottled waters contain fewer amounts of dissolved ions or salts than the sachet brands, though comparatively they are all of good standard in relation to conductivity limit.

All the bottled and sachet drinking water brands had colour below detection limit, with zero values obtained; and thus within the WHO/GSA standard range. This means that all the water brands were free from dissolved humic acids. Turbidity values for the bottled water brands analysed were between 0.11 and 0.20 NTU (averaging 0.15 NTU), whilst that of the sachet water ranged from 0.14 to 0.97 NTU (averaging 0.29 NTU). This is shown in Table 1. Noticeably, the bottled water brands were less turbid as compared with the sachet brands. This could be attributed to the fact that, the bottled water passes through series of filters, or efficient filter medium during production to remove suspended clay particles, trace elements and suspended solids compared to the sachet water. Notably, all the values of turbidity were far below the WHO/GSA standard limit of 5 NTU. This could also account for the reason why all the brands of bottled and sachet waters had zero values of suspended solids and thus, clearer colour below detection limit, which is good for consumption. Total Dissolved solids content for the bottled drinking water ranged from 3.61 to 55.80 mg/L (averaging 21.36 mg/L), whereas values between 10.60 and 87.80 mg/L (averaging 41.15 mg/L) were obtained for the sachet drinking water, as compared with the GSA values of 1000mg/L (See Table 1). This indicated that both the sachet and bottled water analyzed had total dissolved solids concentration within the GSA permissible limits.

Table 1. Physical quality parameters of bottled and sachet water brands analysed

WATER BRANDS	TEMPERATURE (° C)	COLOUR (HU)	CONDUCTIVITY (μs/cm)	TSS (mg/L)	TURBIDITY ((NTU)	TDS (mg/L)
WHO/GSB	***25***	***0-15***	***0-1000***	–	***0-5***	***1000***
Bottled Water						
VOLTIC	29.30 (4.56) [a]	0.00	93.20	0.00	0.20	55.80
SAFINA	29.10 (4.35) [a]	0.00	33.50	0.00	0.11	20.00
AQUAFILL	28.70 (3.92) [a]	0.00	39.30	0.00	0.15	16.90
EVERPURE	28.80 (4.03) [a]	0.00	17.67	0.00	0.14	10.50
BONAQUA	28.80 (4.03) [a]	0.00	5.93	0.00	0.16	3.61
Sachet Water						
COOL PAL	28.90 (4.14) [a]	0.00	94.30	0.00	0.24	56.00
CHOICE	28.90 (4.14) [a]	0.00	55.00	0.00	0.20	33.00
K'POLY	28.90 (4.14) [a]	0.00	146.60	0.00	0.36	87.80
PREMA	28.80 (4.03) [a]	0.00	47.60	0.00	0.24	28.60
EVERPURE	28.80 (4.03) [a]	0.00	47.60	0.00	0.14	10.60
ROYAL	29.00 (4.24) [a]	0.00	51.50	0.00	0.21	29.00
KANDEGLO	28.80 (4.03) [a]	0.00	52.90	0.00	0.29	31.60
AMKESS	28.40 (3.61) [a]	0.00	49.70	0.00	0.25	37.50
CENTURY	28.90 (4.14) [a]	0.00	75.50	0.00	0.22	45.50
PASKY	28.80 (4.03) [a]	0.00	46.70	0.00	0.37	28.00
MOON 'N' STARS	28.70 (3.92) [a]	0.00	22.80	0.00	0.18	13.80
AMRITA	28.90 (4.14) [a]	0.00	57.00	0.00	0.26	17.90
NOVENA	28.90 (4.14) [a]	0.00	94.10	0.00	0.97	56.70
YAAPIS	28.80 (4.03) [a]	0.00	136.90	0.00	0.27	82.10
LILY	28.70 (3.92) [a]	0.00	136.90	0.00	0.23	82.10

WATER BRANDS	TEMPERATURE (° C)	COLOUR (HU)	CONDUCTIVITY (µs/cm)	TSS (mg/L)	TURBIDITY ((NTU)	TDS (mg/L)
SIS. COMFORT	28.80 (4.03) [a]	0.00	85.00	0.00	0.24	29.70
SOLIDAD	28.80 (4.03) [a]	0.00	48.60	0.00	0.24	29.70

– No standard value provided
Standard deviation in parenthesis; number of samples per brand = 9
[a] Statistically differs significantly at 95% (0.05) confidence level from the WHO/GSB standard

3.2. Chemical quality parameters

Table 2 gives the results of pH, hardness (total, calcium and magnesium), alkalinity and chloride of bottled and sachet drinking water brands examined. As shown in Table 2, the pH values of the bottled water samples varied from 6.46 to 6.98 (averaging 6.67), with 60% of the samples having pH values within the WHO/GSA limits, and 40% statistically different at 95% (0.05) confident level below the lowest pH limit of 6.5. In contrast, only 5.88% of the sachet water samples differed significantly at 95% (0.05) confident level below the WHO/GSA lowest pH limit, whilst 94.12% of the samples had pH values within the WHO/GSA range; with values between 6.31 and 7.19 (averaging 6.76). Surprisingly, only 5.88% of sachet water brands had pH values below the requirement by WHO/GSA compared with 40% of the bottled water brands. However, pH values of drinking water below 6.5 is not harmful in residential applications or consumption, but only known to cause corrosion to metal pipes that may result in elevated levels of certain undesirable parameters from corrosion such as copper, lead, or zinc in tap water (Ministry of the Environment, 2006).

All the bottled drinking water brands were very soft in terms of hardness, with values ranging from 2.00 to 12.00 mg/L (averaging 9.60 mg/L). Variable hardness properties were obtained for the sachet water brands – 70.59% were very soft (< 17 mg/L), 17.65% slightly soft (17–51 mg/L), and 11.76% moderately hard (51–120 mg/L); with average hardness value of 17.77 mg/L. The average calcium hardness for the sachet water samples was 11.29 mg/L and that of magnesium was 6.75 mg/L, as compared with the bottled water samples with calcium and magnesium hardness of 4.40 and 5.20 mg/L respectively (See Table 2). Importantly, the hardness contents obtained for the bottled and sachet drinking water brands does not necessarily indicate that the water poses a health risk as no standard values were given by WHO.

From the results obtained in the study, the average alkalinity for the bottled water samples was 28.40 mg/L, with values between 14.00mg/L and 70.00 mg/L, whereas values of sachet water ranged from 14.00 to 70.00 mg/L (averaging 32.47 mg/L). Though values of alkalinity of the bottled samples were averagely below that of sachet samples, all were below the WHO/GSA standard of 500 mg/L. Similarly, chloride content of both the sachet and bottled water samples was below the WHO/GSA standard of 250 mg/L. Averagely, the sachet water samples had lower chloride contents than the bottled samples with average values of 37.41mg/L and 43.60 mg/L respectively.

Table 2. Chemical quality parameters of sachet and bottled water brands

WATER BRANDS	pH	CALCIUM HARDNESS (mg/L)	TOTAL HARDNESS (mg/L)	ALKALINITY (mg/L)	CHLORIDE (mg/L)
WHO/GSB	***6.5-8.5***	–	–	***500***	***250***
Bottled Water					
VOLTIC	6.47 [0.03] [a]	8.00	22.00	70.00	40.00
SAFINA	6.57	2.00	6.00	24.00	54.00
AQUAFILL	6.89	8.00	12.00	14.00	24.00
EVERPURE	6.98	2.00	2.00	20.00	42.00
BONAQUA	6.46 [0.04] [a]	2.00	6.00	14.00	58.00
Sachet Water					
COOL PAL	7.19	14.00	16.00	52.00	42.00
CHOICE	7.03	4.00	12.00	32.00	36.00
K'POLY	6.95	40.00	68.00	60.00	48.00
PREMA	6.68	6.00	8.00	46.00	30.00
EVERPURE	6.73	2.00	2.00	20.00	44.00
ROYAL	6.65	6.00	8.00	24.00	34.00
KANDEGLO	6.56	6.00	10.00	18.00	40.00
AMKESS	6.71	8.00	14.00	16.00	36.00
CENTURY	6.65	6.00	12.00	22.00	40.00
PASKY	6.57	6.00	10.00	40.00	54.00
MOON 'N' STARS	6.31 [0.20] [a]	2.00	4.00	14.00	22.00
AMRITA	6.79	6.00	20.00	18.00	54.00
NOVENA	6.93	18.00	24.00	70.00	20.00
YAAPIS	6.87	12.00	18.00	16.00	28.00
LILY	6.97	42.00	52.00	44.00	38.00
SIS. COMFORT	7.10	8.00	16.00	16.00	40.00
SOLIDAD	6.60	6.00	8.00	44.00	30.00

– No standard value provided; number of samples per brand = 9
Standard deviation from WHO/GSB lower range standard in square brackets
[b] Statistically differs significantly at 95% (0.05) confident level from the WHO/GSB lower range standard

3.3. Bacteriological quality parameters

Results obtained in this study indicated that bottled and sachet water sold in various part of the Kumasi Metropolis are free from microbiological contaminants, as shown in Table 3. Total coliforms, faecal coliforms and enterococci were not isolated in any of the five (5) different brands and triplicates samples of bottled drinking water, and seventeen (17) different brands and triplicates samples of sachet drinking water (See Table 3). The presence of total coliforms in treated drinking water is a measure of its general sanitary quality whereas the indication of faecal contamination is measured by the presence of faecal coliforms (Ashbolt et al., 2001). WHO/GSA limit is that none should be detected in drinking water (WHO, 2001, 2002). This clearly indicated that bottled and sachet water sold in Kumasi are of good microbiological quality, and thus suitable for human consumption.

Table 3. Bacteriological quality parameters of sachet and bottled water brands

WATER BRANDS	BACTERIA COUNTS (CFU/100ml)	TOTAL COLIFORM (CFU/100ml)	FAECAL COLIFORM (CFU/100ml)
WHO/GSB	0.00	0.00	0.00
Bottled Water			
VOLTIC	ND	ND	ND
SAFINA	ND	ND	ND
AQUAFILL	ND	ND	ND
EVERPURE	ND	ND	ND
BONAQUA	ND	ND	ND
Sachet Water			
COOL PAL	ND	ND	ND
CHOICE	ND	ND	ND
K'POLY	ND	ND	ND
PREMA	ND	ND	ND
EVERPURE	ND	ND	ND
ROYAL	ND	ND	ND
KANDEGLO	ND	ND	ND
AMKESS	ND	ND	ND
CENTURY	ND	ND	ND
PASKY	ND	ND	ND
MOON 'N' STARS	ND	ND	ND
AMRITA	ND	ND	ND
NOVENA	ND	ND	ND
YAAPIS	ND	ND	ND
LILY	ND	ND	ND
SIS. COMFORT	ND	ND	ND
SOLIDAD	ND	ND	ND

Number of samples per brand = 9; ND = not detected (i.e. no gas produced, or no growth detected, i.e. 0.00 CFU/100 ml)

Earlier investigations conducted by Obiri-Danso et al. (2003), on the safety of drinking water in Kumasi reported good microbiological quality of bottled water whereas that of some plastic bagged drinking water was found to be suspicious. The improved results obtained in the sachet drinking water samples analyzed, compared to this earlier report indicated that producers of sachet drinking water in Kumasi has improved upon the quality standards of their production processes and post-production (handling) practices over the past years.

4. Conclusion

The physical, chemical and bacteriological quality properties of randomly selected bottled and sachet drinking water brands sold and/or produced in the Kumasi Metropolis were analysed successfully. Though temperature values of all the bottled and sachet drinking water samples were significantly above the WHO/GSB standard, it did not have any effect on their microbiological quality properties. Total coliforms, faecal coliforms and enterococci bacteria that principally characterises drinking water quality were not present in any of the water samples. Generally, the results obtained in this study indicated that bottled and sachet drinking water sold and/or produced in Kumasi were of good quality and hygienic for consumption.

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